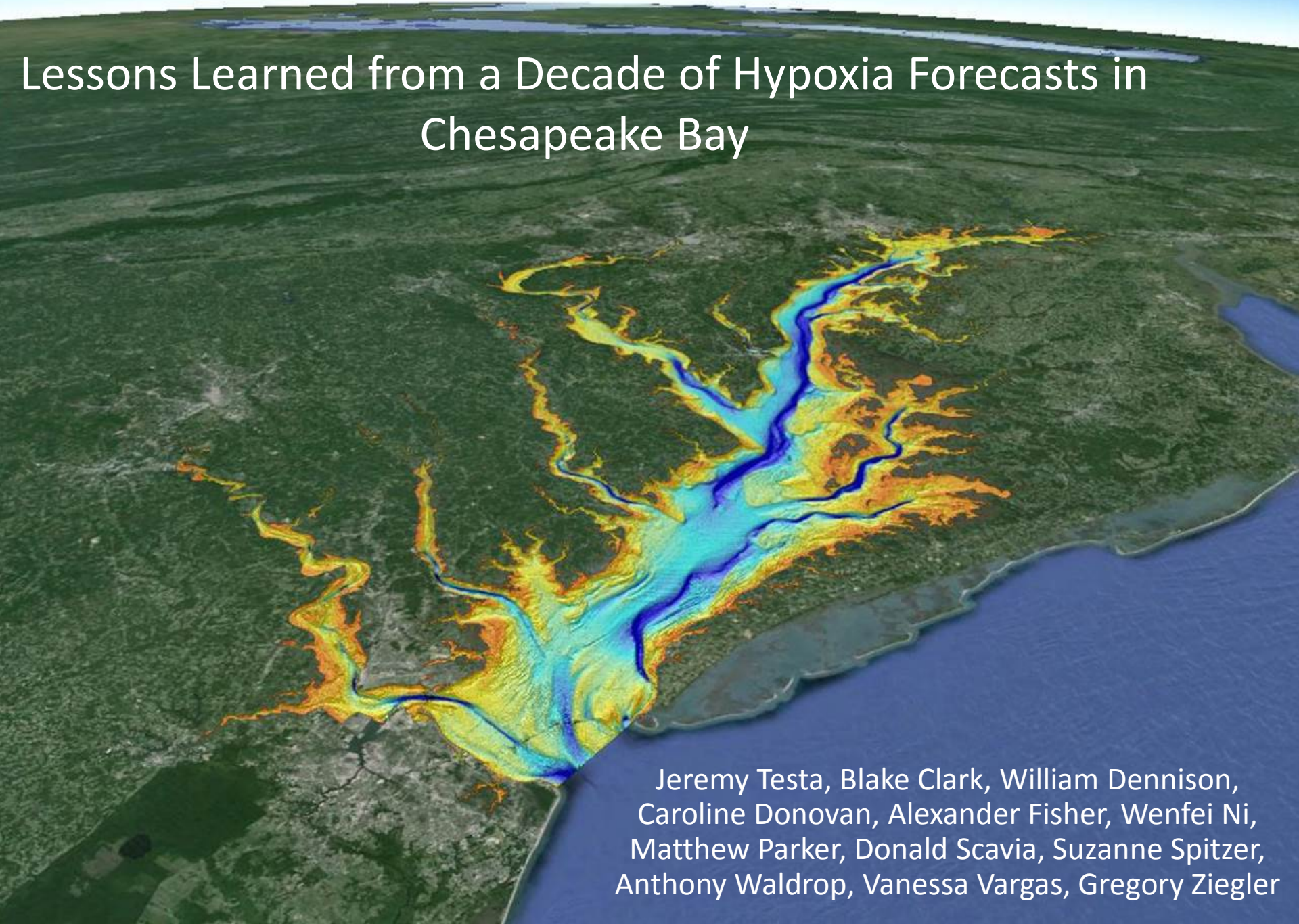
Lessons Learned from a Decade of Hypoxia Forecasts in Chesapeake Bay



Jeremy Testa, Blake Clark, William Dennison, Caroline Donovan, Alexander Fisher, Wenfei Ni, Matthew Parker, Donald Scavia, Suzanne Spitzer, Anthony Waldrop, Vanessa Vargas, Gregory Ziegler

A Multi-Institutional Effort

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Gregory Ziegler

Wye Research and Education Center

Donald Scavia

Graham Sustainability Institute, University of Michigan

Maryland DNR, USEPA Chesapeake Bay Program
USGS, NOAA, many past forecasters

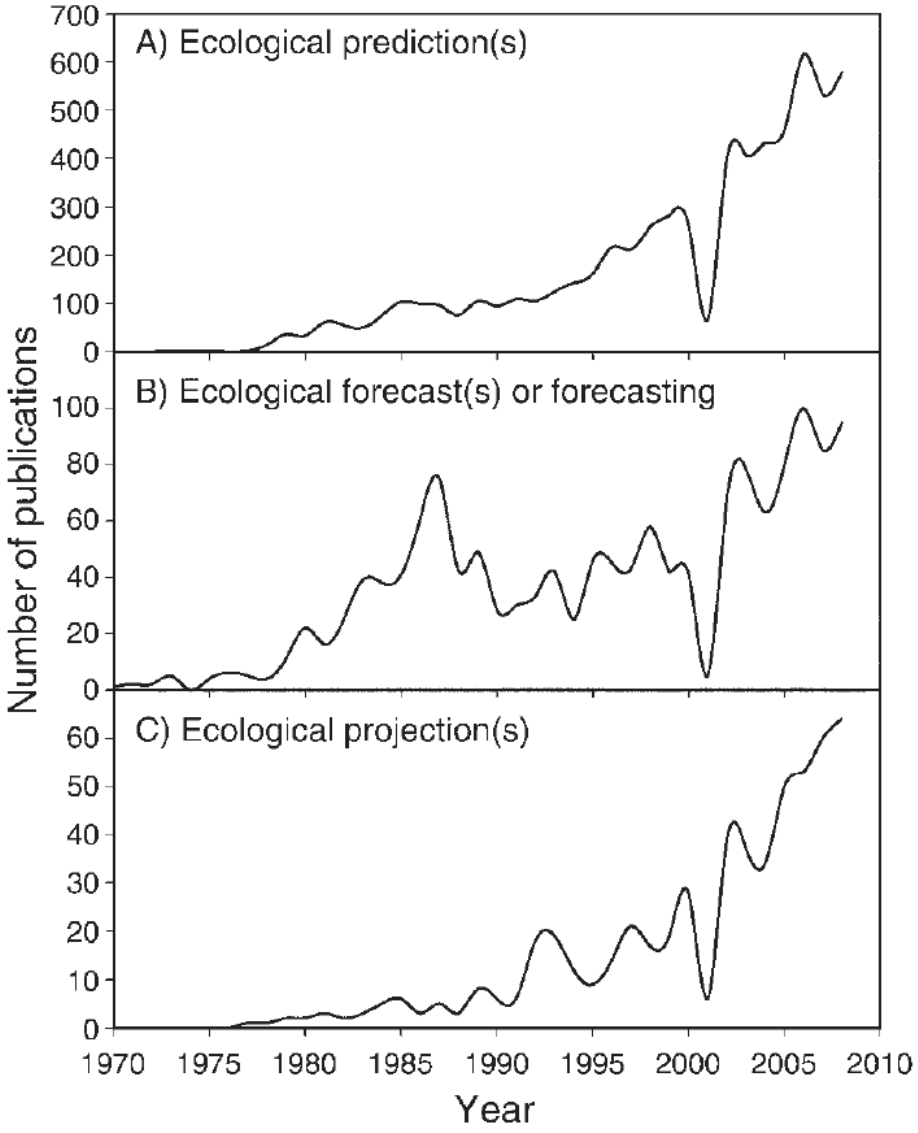
An Overview

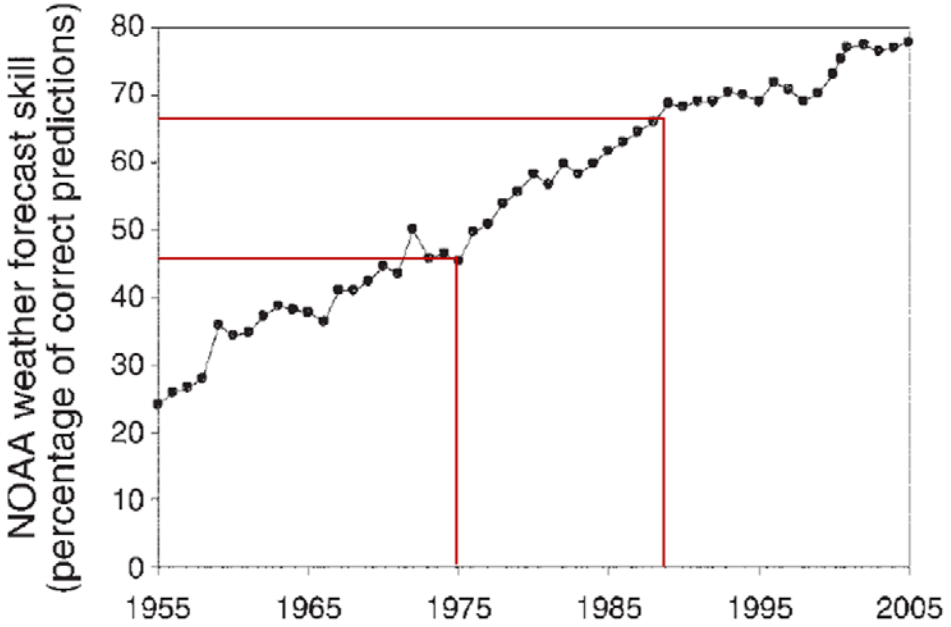
- The Hypoxia Problem
- Chesapeake Bay Hypoxia and a Science History
- Forecasting Hypoxia – Why? Can it be done?
- What is the Impact of Hypoxia Forecasting
- Looking Ahead

Ecological Forecasting and the Science of Hypoxia in Chesapeake Bay

JEREMY M. TESTA, J. BLAKE CLARK, WILLIAM C. DENNISON, E. CAROLINE DONOVAN, ALEXANDER W. FISHER, WENFEI NI, MATTHEW PARKER, DONALD SCAVIA, SUZANNE E. SPITZER, ANTHONY M. WALDROP, VANESSA M.D. VARGAS, AND GREGORY ZIEGLER

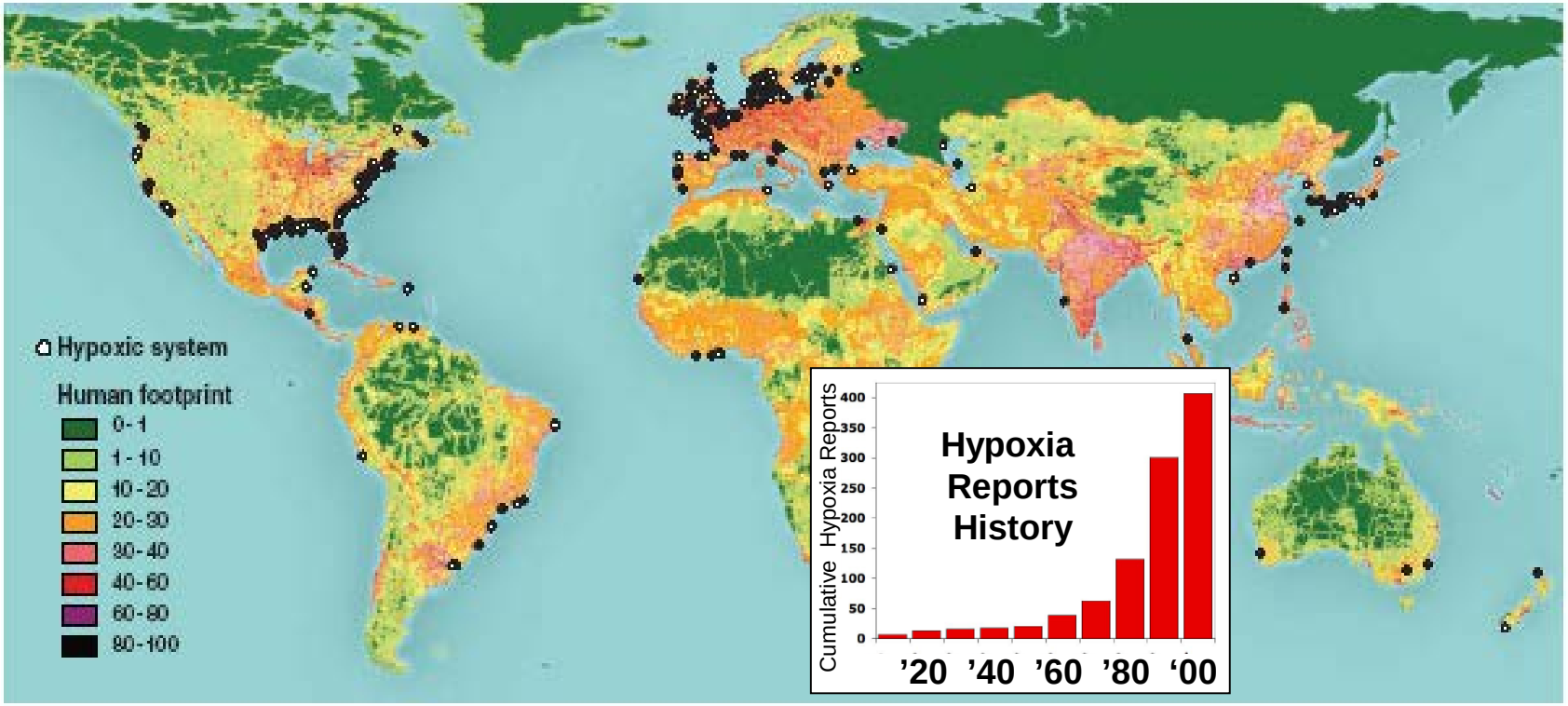
Ecological Forecasting: Increasingly Common and It Gets Better with Age





Luo et al. 2011

Coastal hypoxia is a global phenomenon, has worsened in many

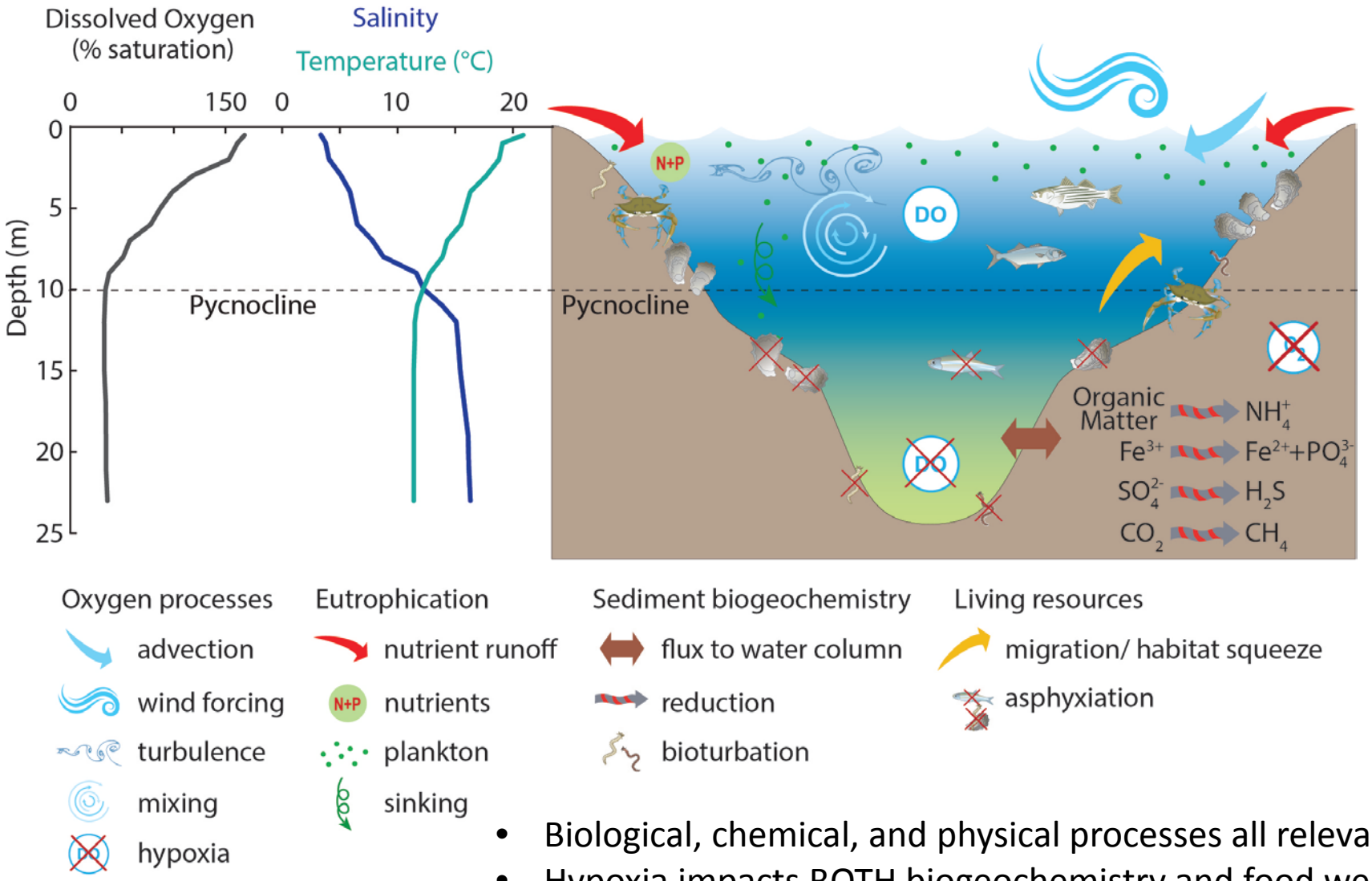


• Recent (2008) survey identified > 400 reported systems with hypoxia due to eutrophication; expanded to more regions covering ~250,000 km^2.

• Hypoxia distribution linked with watershed regions having large human "footprint" (i.e., intense human activity and influence).

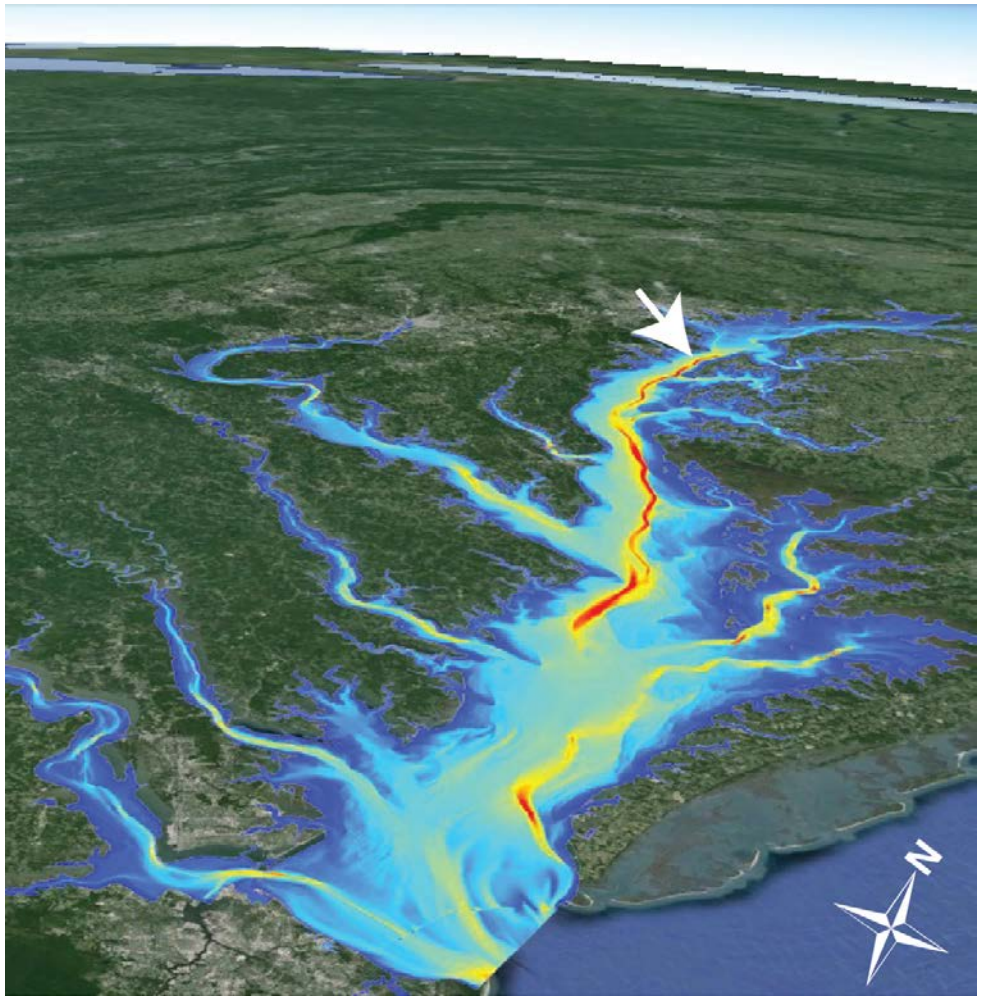
(Diaz & Rosenberg 2008)

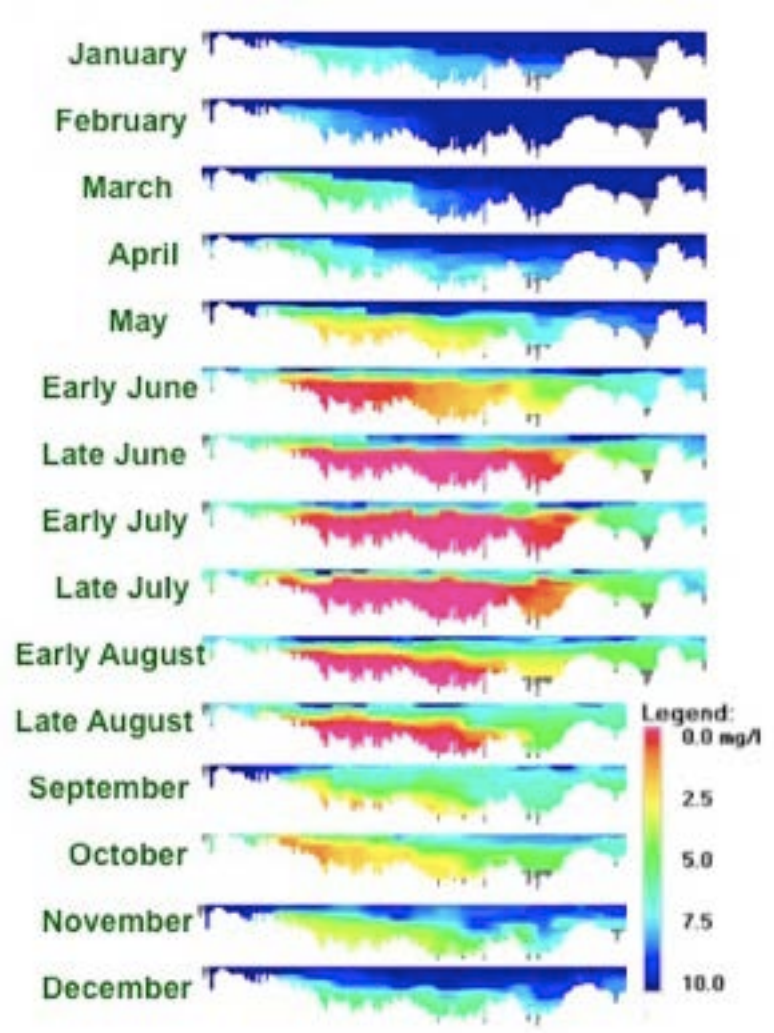
Hypoxia Influenced by Many Factors, Has Many Negative Impacts



- Biological, chemical, and physical processes all relevant
- Hypoxia impacts BOTH biogeochemistry and food web

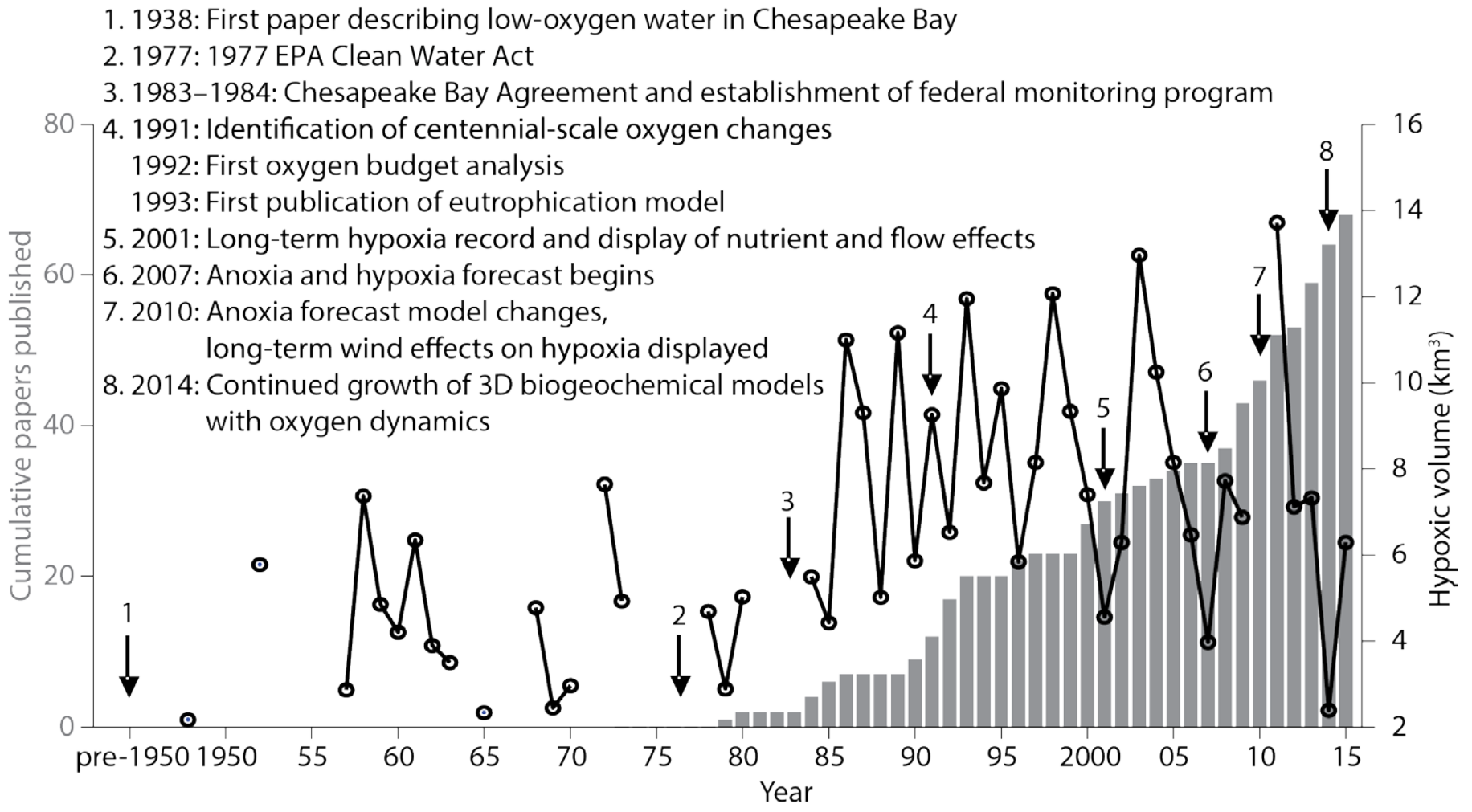
Chesapeake Bay Hypoxia





- Chronic seasonal hypoxia in Chesapeake Bay
- Hypoxia linked to eutrophication originating from watershed inputs
- Seasonal hypoxia largely confined to deep water channel in Chesapeake Bay (red, yellow)

Severity of hypoxia accompanied by increased scientific interest

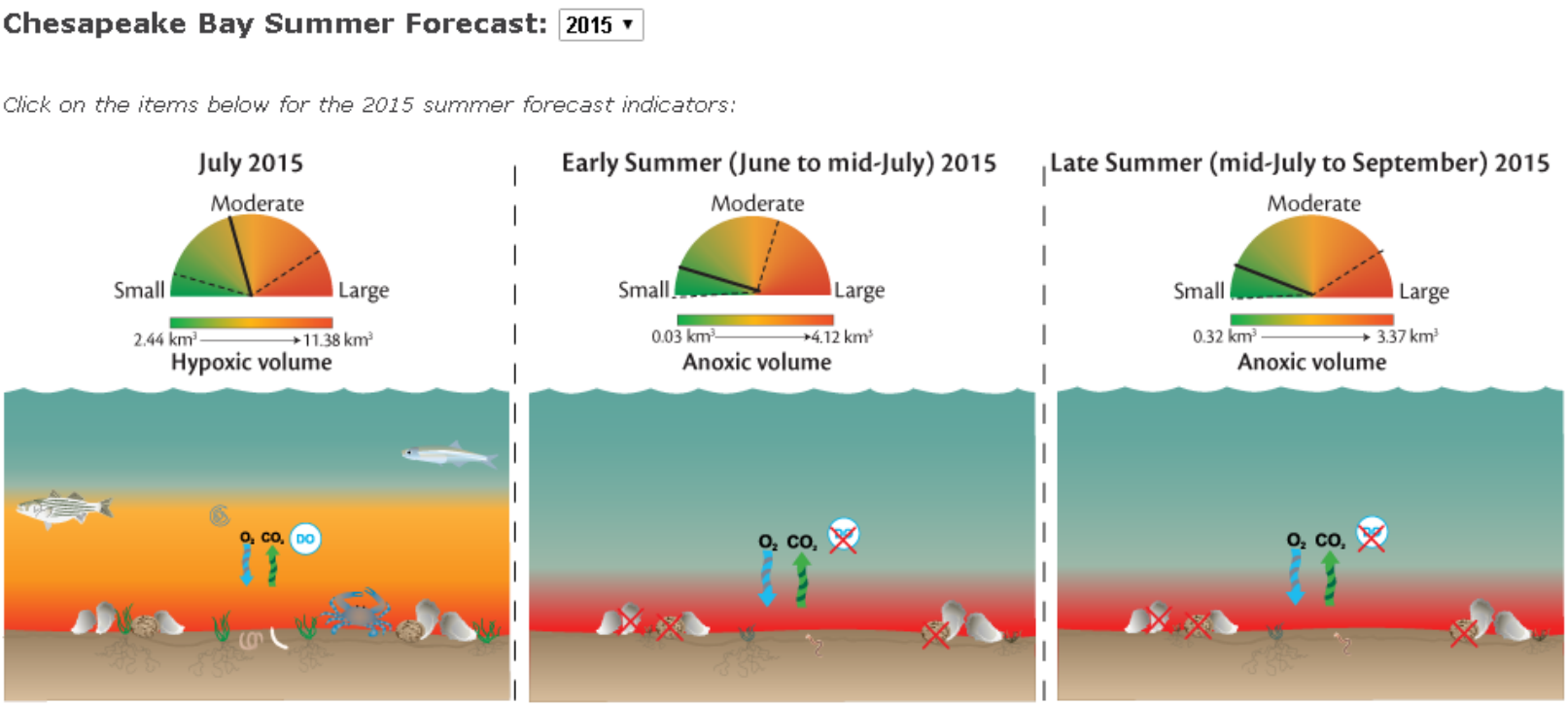


Why forecast hypoxia?

- Oxygen is a keystone molecule for life
- Hypoxia integrates the response to a variety of point and nonpoint source nutrient inputs, as well as physical forces – test of knowledge
- Considerable management efforts being made to reduce eutrophication that leads to hypoxia
- Legacy of scientific research AND Bay monitoring has allowed for reasonable predictive models

Forecast Models

Three models have been used to forecast summer hypoxia and anoxia in Chesapeake Bay



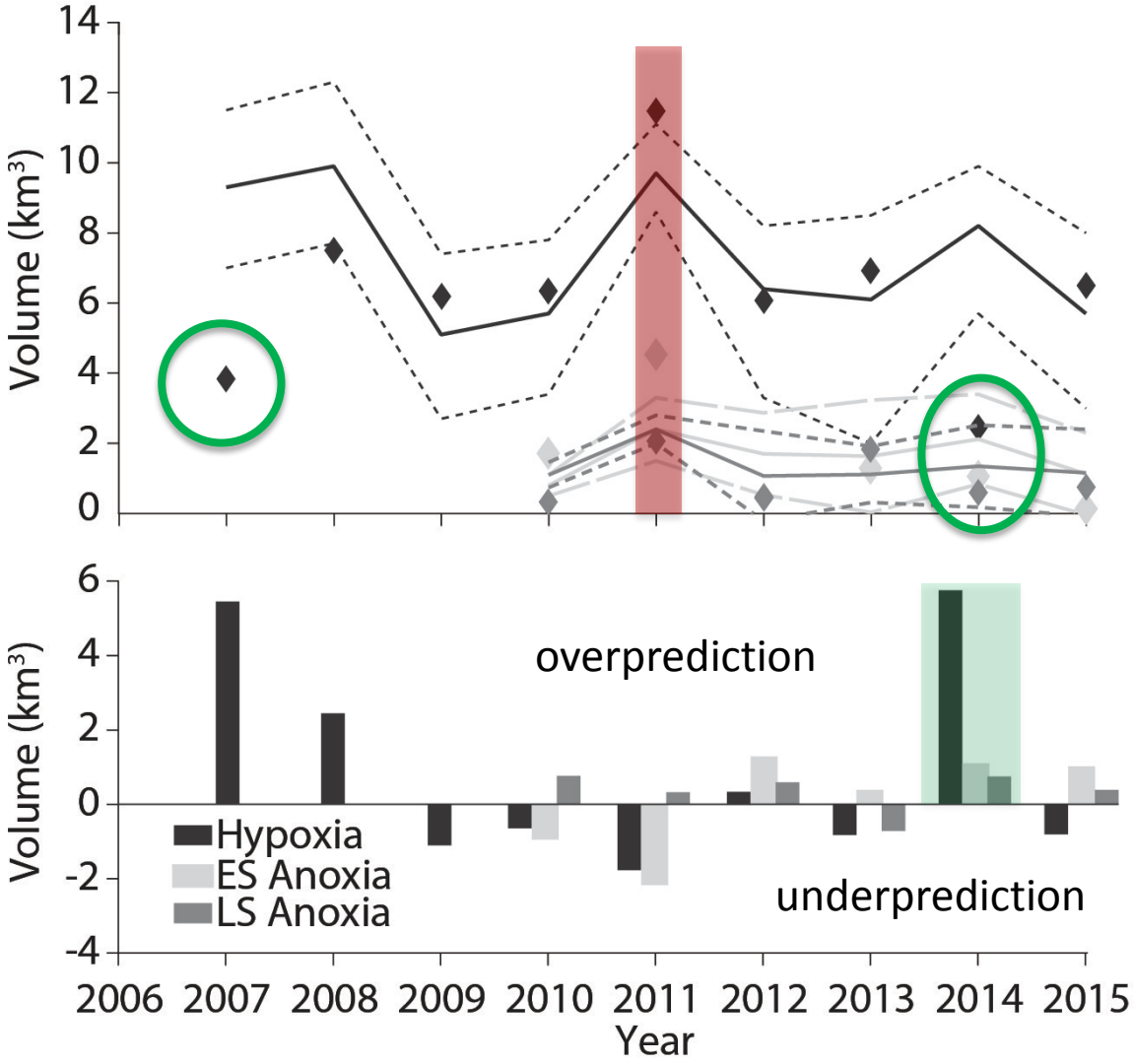
July Average Hypoxia
$O_2 < 2$ mg/L

Early Summer
$O_2 < 0.2$ mg/L

Late Summer
$O_2 < 0.2$ mg/L

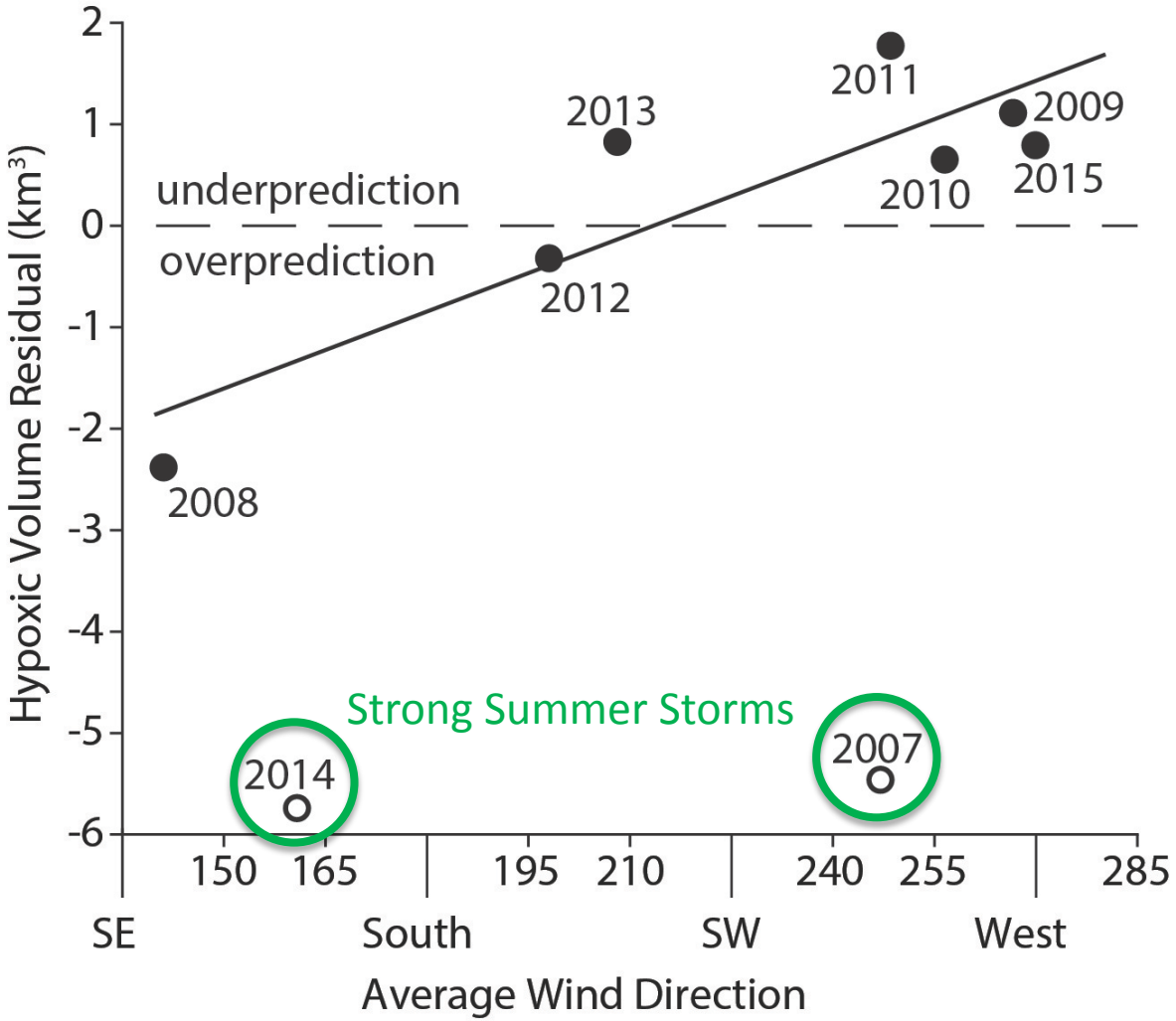
- All models forecast hypoxia and or anoxia based on winter-spring nutrient inputs
- http://ian.umces.edu/ecocheck/forecast/chesapeake-bay/2017/
- Anoxia models are regression based, hypoxia model is a modified oxygen sag model
- Each fall, forecast is evaluated with a *Summer Review*

How Have the Forecasts Performed?

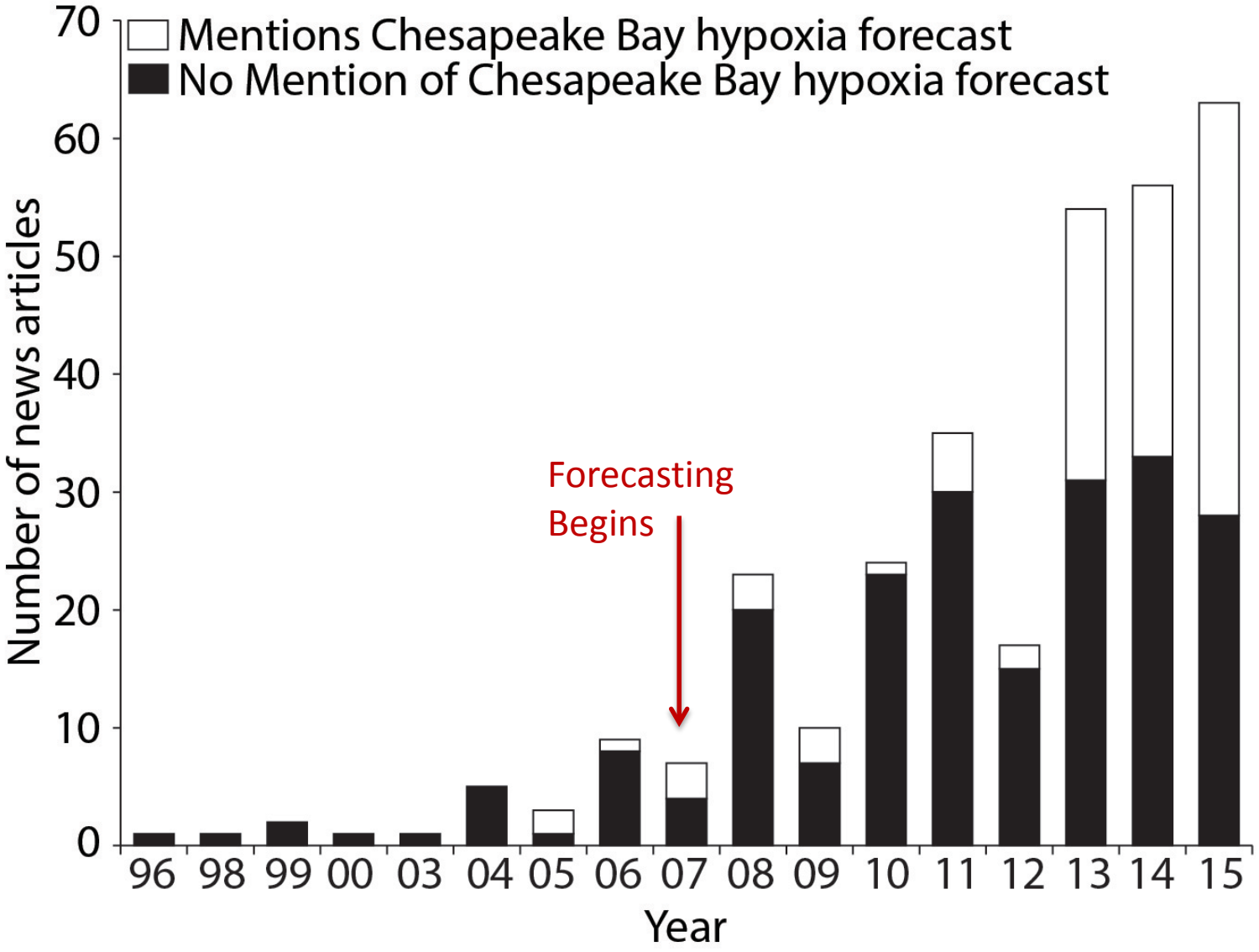


- All models have routinely forecast low-oxygen volumes with success
- There has been a slight tendency for over-prediction of anoxic volumes

Summer Wind Direction (and speed) Affects Hypoxia Forecasting Success



Increased Media Interest in Hypoxia and Forecasting

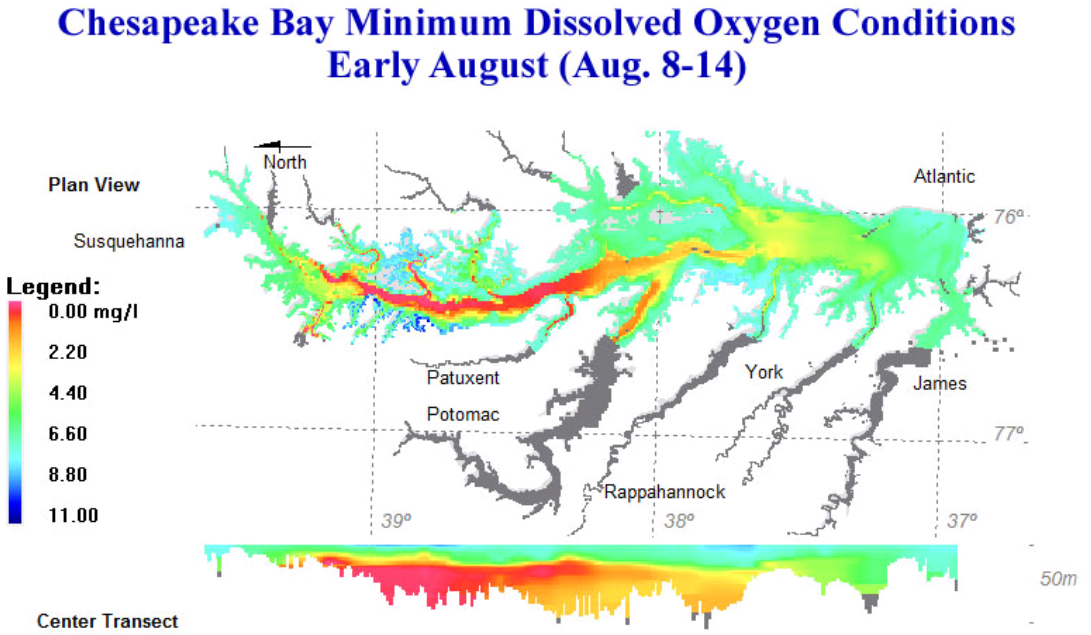


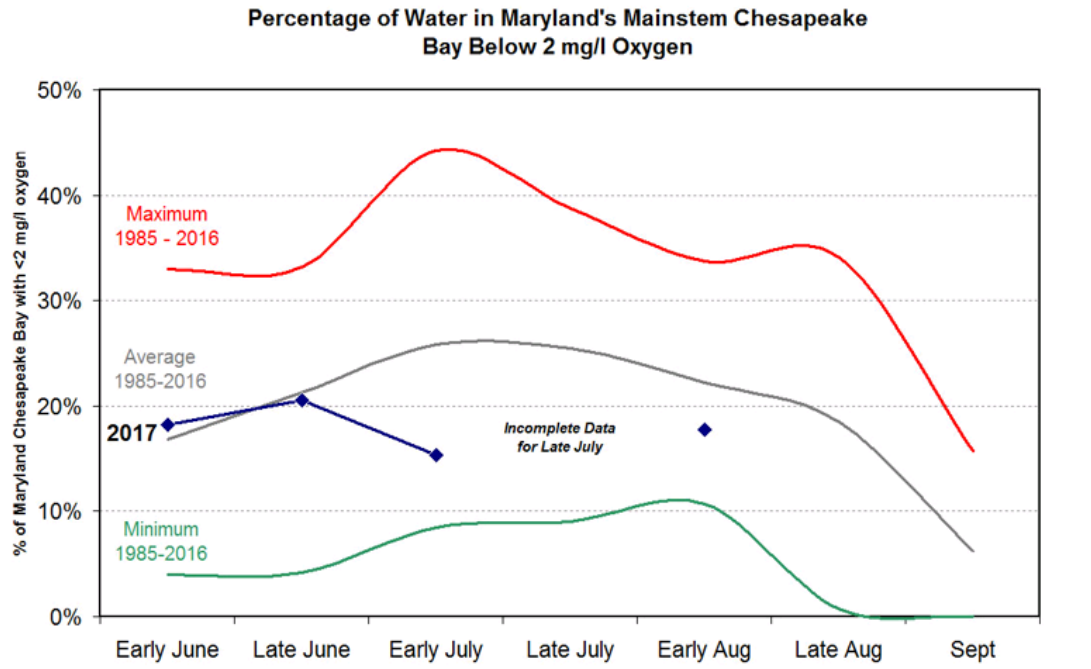
Lessons Learned

- Hypoxia forecasting in Chesapeake Bay has been a success, but there is room for improvement
- Hypoxia forecast raised public awareness for Chesapeake Bay hypoxia issues
- The forecasts helped communicate the complex ecology of the Bay in a dynamic and widely accessible format
- Forecast models only developed after decades of research and especially, monitoring – we need to maintain monitoring efforts!

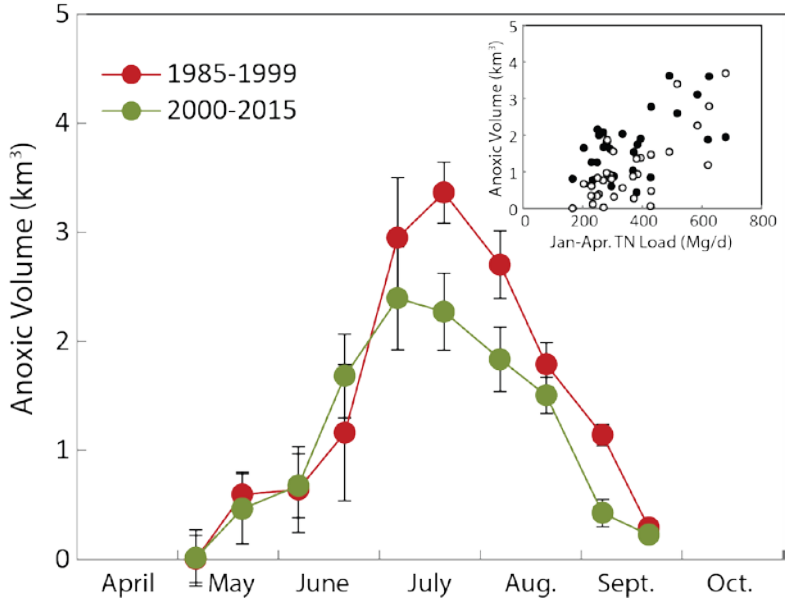
2017

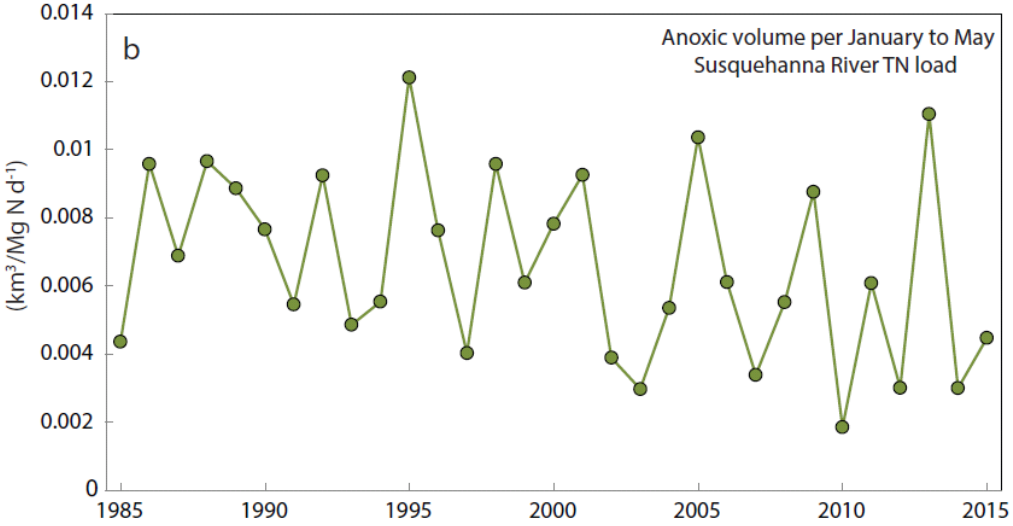
- Forecasts called for above average conditions
- Initial estimates indicate lower than average volumes
- Early August maps reveal a deep water intrusion of relatively oxygenated water
- Why?

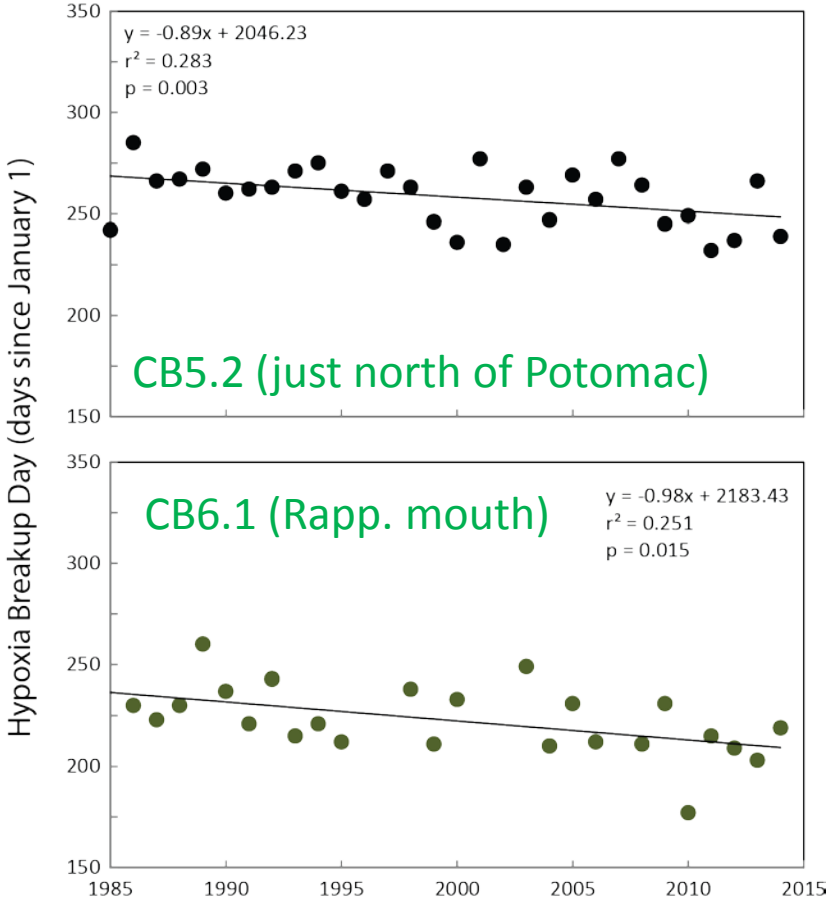




2017 Pattern Consistent with Season- and Region-Specific Trends







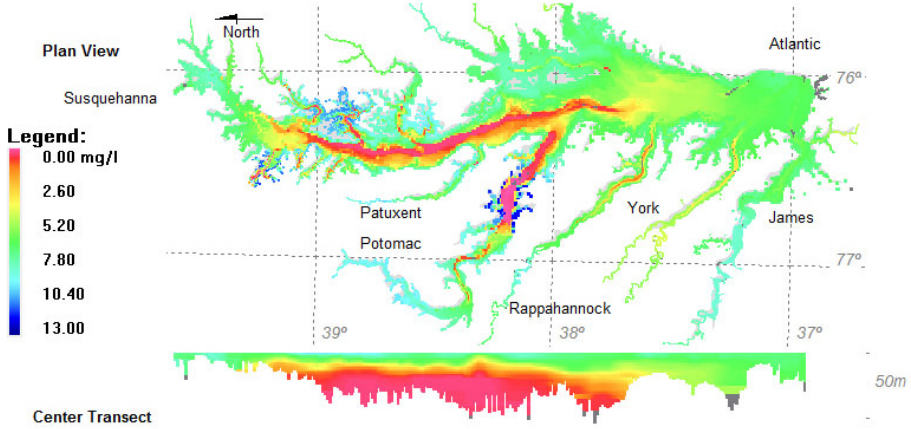
Testa, Murphy, Brady & Kemp, in prep
Testa et al. (2017)


Thank You

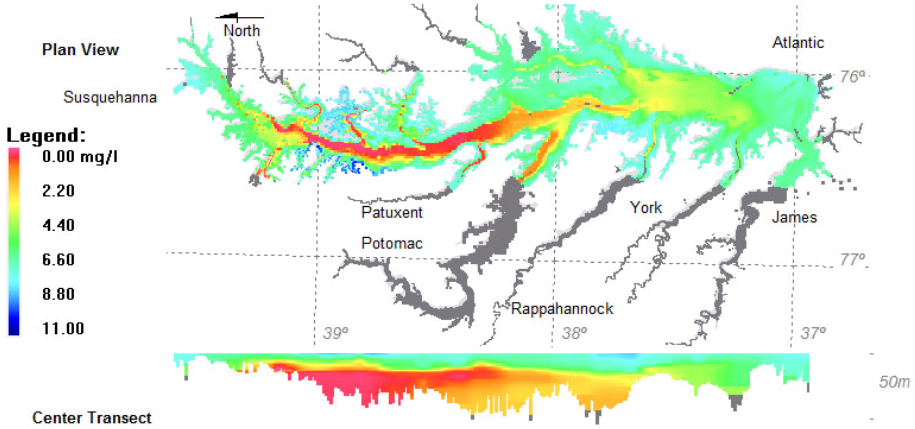
Year

Chesapeake Bay Minimum Dissolved Oxygen Conditions

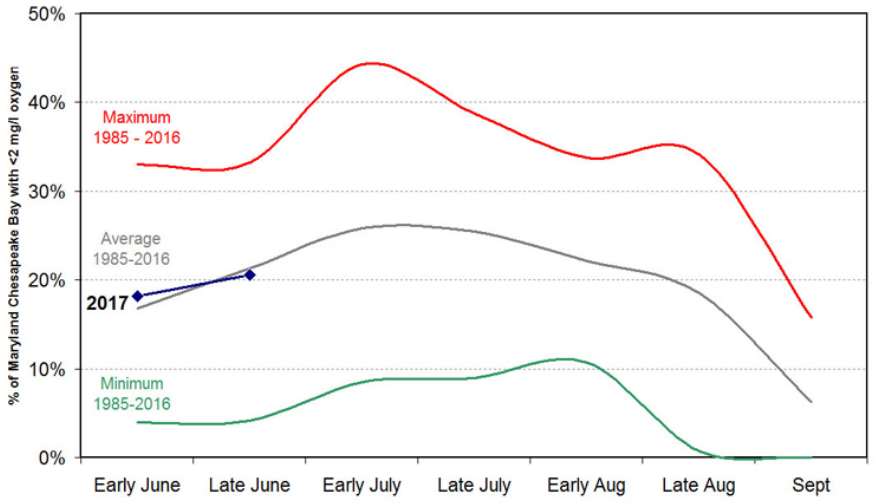
Late June Main Bay (Week of June 24)
and Monthly Tributary (June 1-28) Data



Chesapeake Bay Minimum Dissolved Oxygen Conditions Early August (Aug. 8-14)



Percentage of Water in Maryland's Mainstem Chesapeake Bay Below 2 mg/l Oxygen



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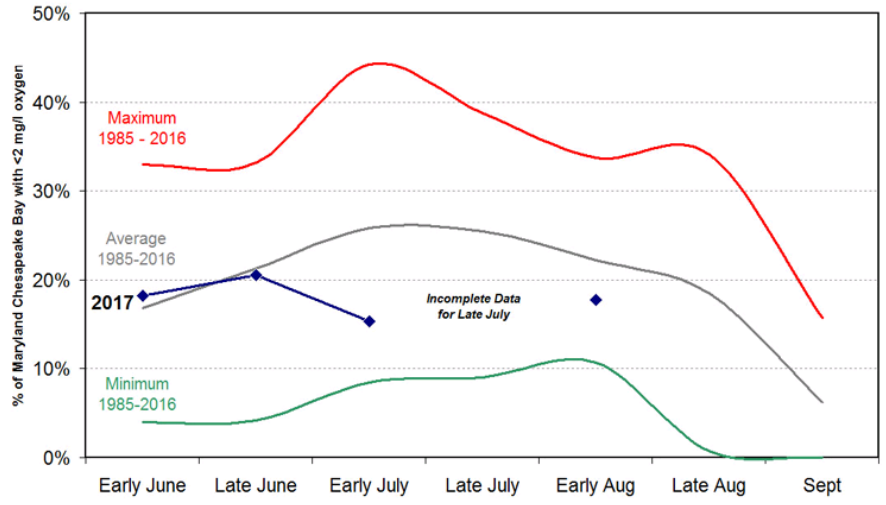

Recommendations for hypoxia forecasting

- Build longer term skill assessment track records and consider adding new information, such as longer range weather forecasts

- Use multiple models. Multiple model approaches are common in developing climate and hurricane projections, and increasingly common in natural resource issues (Bierman et al. 1980, Scavia et al. 2004, Scavia et al. 2016, Stow et al. 2003, Weller et al. 2013).

- Communicate forecasts in clear and consistent manners, especially from multiple models, using visualizations and narratives of forecasts, observations, and drivers, and report potential events that can affect the forecast (e.g., hurricanes, droughts) when forecasts are made and update routinely

- Add 3D forecasts to the suite. These short-term forecasts will be of great use because they provide spatially-explicit maps of expected low DO conditions.

Media Interest is National and Local

Bay Journal

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Average dead zone predicted for this summer

By Karl Blankenship on June 01, 2007 *Comments are closed for this article.*

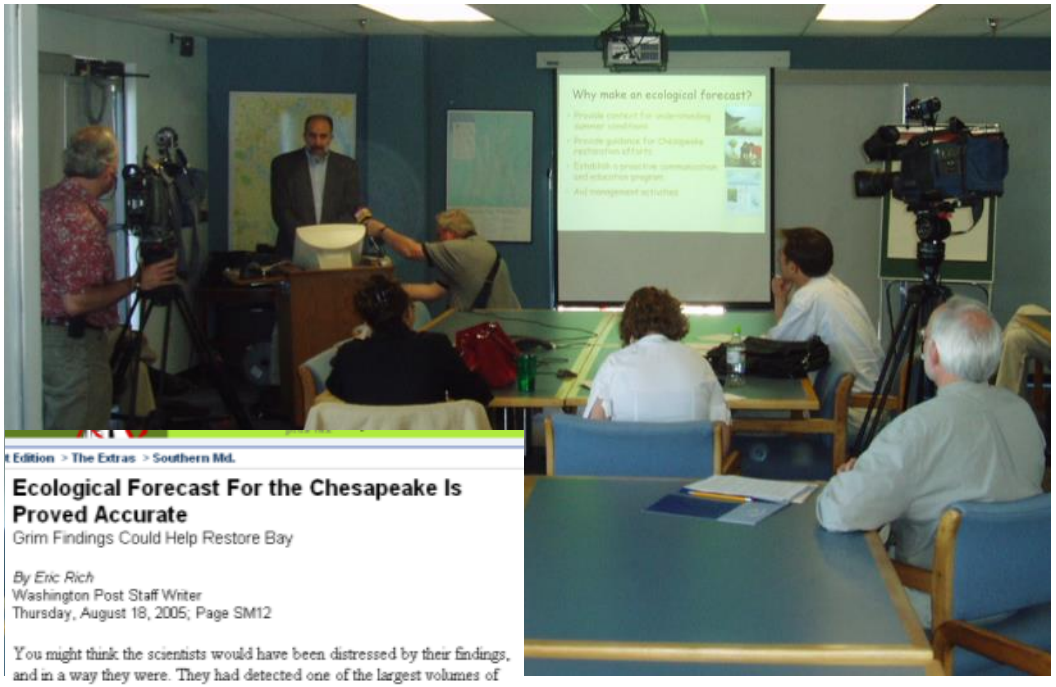
Scientists predict the Bay's oxygen-depleted "dead zone" will be almost exactly average in size this year.

In their third annual forecast, they predict that from June through September, an average of 1.39 cubic kilometers—or 2.6 percent of the Bay's mainstem, will be anoxic—essentially having no oxygen. That makes it off-limits to almost all Bay creatures.

If that prediction holds up, 2007 would rank 11th when compared with the previous 22 summers, according to Dave Jasinski, a University of Maryland Center for Environmental Science analyst.

That would be worse than last summer when, on average, the amount of anoxic water in the Bay was 0.93 cubic kilometers, or 1.79 percent of the Bay's total volume. Last year was the seventh best year since Baywide water quality monitoring began in 1985.

But it would be a significant improvement from 2005, which was the fifth worst summer on



t Edition > The Extras > Southern Md.

Ecological Forecast For the Chesapeake Is Proved Accurate

Grim Findings Could Help Restore Bay

By Eric Rich
Washington Post Staff Writer
Thursday, August 18, 2005; Page SM12

You might think the scientists would have been distressed by their findings, and in a way they were. They had detected one of the largest volumes of oxygen-depleted water ever recorded in the Chesapeake Bay -- more than 900 billion gallons that could not sustain a rockfish, blue crab or any of the bay's other cherished species.

Yet the bad news was, in a sense, good as well. Researchers dedicated to untangling the complexities of the nation's largest estuary had found more or less what they predicted in their first attempt at ecological forecasting.

"We're pretty happy in a macabre sense that our actual forecast is coming true," said Bill Dennison, a professor at the University of Maryland Center for Environmental Science. "We're not happy with the condition of the bay. We're just satisfied that we got it right."

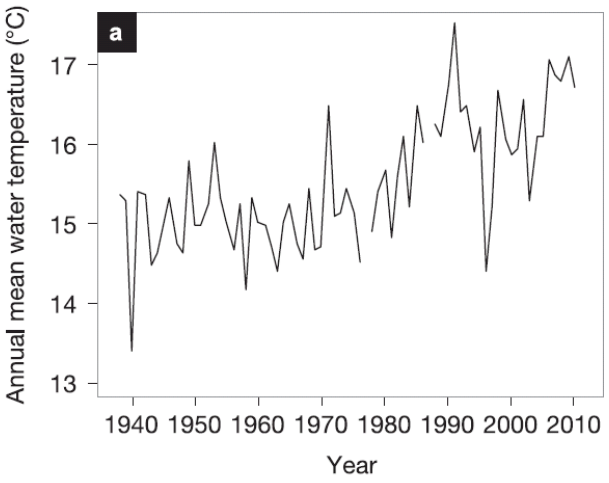
The scientists found last month that 6.7 percent of the bay's main section is anoxic, meaning it contains no more than 0.2 milligrams of dissolved oxygen per liter and, therefore, is lethal to almost all fish and shellfish.

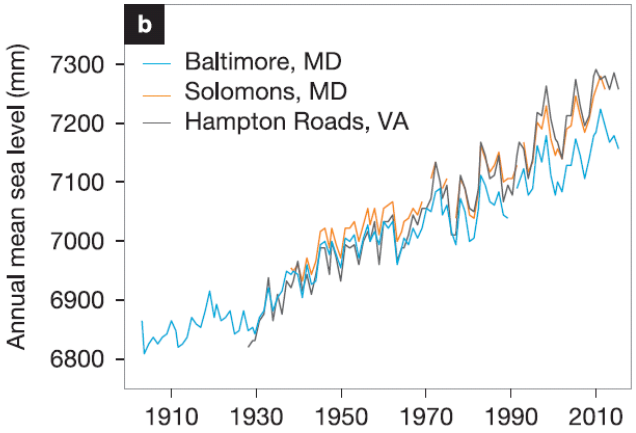
The forecast was issued in early May by researchers working with the Chesapeake Bay Program, a restoration effort that includes federal and state agencies and other partners. They predicted that, in terms of anoxia, this summer would rank among the five worst in the past 20 years and that it would mirror the summer of 1998 for the level of anoxic water.

Indeed, the level detected during a survey from July 11 to 15 was greater than in comparable July surveys in all but three of the past 20 years. The numbers are "definitely not good," said David Jasinski, Chesapeake Bay Program data analyst. "But our prediction basically said this was not going to be a good year for dissolved oxygen."

Climate change will affect Chesapeake Bay hypoxia and forecasting

- Increased temperature
- Increased salinity
- Sea level rise
- Increased precipitation variability
- Wind?





Climate change influences the ocean hypoxic conditions directly (i.e. the availability of oxygen) and indirectly (changes in sea-level, temperature, freshwater inputs, and changes in wind)